Hybrid Model RFID Anti-collision Algorithm

Robithoh Annur[1], Suvit Nakpeerayuth[2], Lunchakorn Wuttisittikulkij[2]
[1]Department of Computer and Communications Technology ,Malaysia
[2]Department of Electrical Engineering Chulalongkorn University ,Bangkok, Thailand
robithoh@utar.edu.my, wlunchak@chula.ac.th

Abstract
This paper addresses the problem of tags collision in an RFID network. We proposed a simple mechanism for tag anti collision algorithm that includes framed slotted Aloha and tree algorithm. The framed slotted Aloha is used to estimate the number of collided tags. The process continues with the dynamic tree algorithm by splitting the collided tags into the number estimated tags. The results show that the frame size for the estimation step has significant effect to the system efficiency. The maximum system efficiency achieved by the proposed algorithm is 40.03%.

1. Introduction

Generally, an infrastructure wireless access network consists of a central base station and several wireless user terminals who communicate between them over a common wireless channel. In such a network, users are usually geographically distributed over the service area and generally uncoordinated. Radio Frequency IDentification (RFID) is one of a modern infrastructure wireless technology that is mainly applied in object identification tracking system. This technology gets more attention and more likely replaces the existing barcode system since it does not require line of sight. Moreover, an RFID reader is able to identify multiple tags in almost a simultaneous time.

There are three main components in an RFID system namely at least a reader that identifies the tags, tag that is attached to the object, and data base system to store the information about the objects [1]. The reader acts as the base station and the tags is the user terminals. Since they communicate through a single channel, during the identification process, an RFID system may face a problem namely tags collision whereby at least to tags sending their responses at exactly the same time. This results in longer identification time.

In literatures, several anti-collision algorithms have been proposed to address the collision problem in RFID systems. They are categorized into Aloha based, tree based and hybrid algorithms. Aloha based anti-collision algorithm includes pure Aloha, slotted Aloha and framed slotted Aloha (FSA) [2,3]. Among these three Aloha based algorithms, framed slotted Aloha (especially dynamic framed slotted Aloha) gains more intention from researchers. The Aloha based algorithms are known to be simple but offers low system efficiency. Tree based algorithms follow the divide and conquer paradigm to resolve the collision whereby the collided tags are recursively split until all the tags are successfully identified [4,5,6]. This algorithm is more complex since the tags are required to keep track their level on the tree structure. However, it can offer high system efficiency. The hybrid anti-collision algorithms combine the two mentioned algorithms aiming to obtain high system efficiency with a very simple mechanism [7].

This paper proposes a hybrid anti-collision algorithm that divides the identification process into two parts. The first part utilizes framed slotted Aloha for tag population estimation, while the second part is dynamic tree algorithm where the first splitting factor is based on the estimation result in the first part. This proposed algorithm is expected to be simple since only one frame is used for the estimation with framed slotted Aloha and the process will continue with dynamic tree algorithm that can offer high system efficiency.

This paper is organized as follows: Section 2 describes the related previous works. Section 3 describes the proposed system model and Section 4 results and discussions. We conclude our work in section 5.

2. Related Works

2.1 Frame Slotted Aloha

The time in framed slotted Aloha is devided into slots. A number of consecutive time slots are further organized into a frame. For the tag identification process, tags send their IDs in a slot of a frame at random. If collision occurs in the frame, the identification process will continue in the next frames. According to the frame size during the identification process, there are two types of frame slotted Aloha: fixed framed slotted Aloha and dynamic framed slotted Aloha [3]. In the fixed framed slotted Aloha, the frame size does not change during the identification process, while in dynamic framed slotted Aloha, the frame size changes dynamically according to the number of tags. The later one obtains more attension from researcher since this can offer high performance compared to the fixed ones. A simple operation of dynamic framed slotted Aloha is given in Figure1.

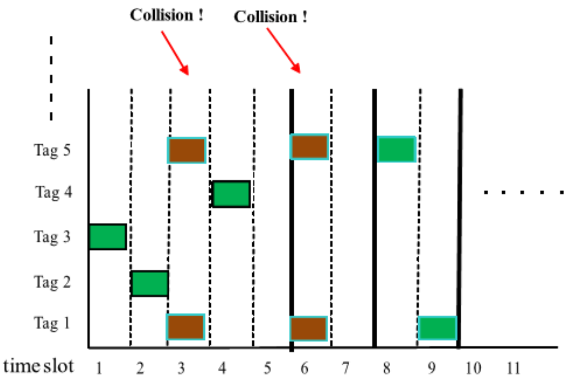

Figure 1 Operation of dynamic framed slotted Aloha

Dynamic framed slotted Aloha can achieve a maximum throughput of of 36.8% when the frame size is exactly the same as the number of unidentified tags. However, setting the frame size to be equal to the number of collided tags is a challenge in dynamic framed slotted Aloha since the number of collided tags is unknown. Therefore, estimating the number of collided tags is required in dynamic framed slotted Aloha.

2.2 Tree algorithm

Tree is a conventional collision resolution algorithm introduced by Capetanakis [4,5,6]. The main concept of this algorithm is to resolve the collision by deviding the collision into smaller group recursively until all the tags are finally identified. All tags related with a collision are divided in *Q* subgroups. Each tag randomly selects the group to contend. The first subgroup immediately retransmits in the first slot and the next subgroups have to wait until the contention in the previous subgroups has been resolved. Indeed, if any reservation slot contains more than one tag, it will result in collision; therefore, this group will split again into *Q* subgroups. The splitting process can be represented in the form of a tree where each collision produces *Q* new branches. Figure 2. shows a tree stucture that illustrates a tag collision resolution with tree algorithm when *Q* is set to 3. It can be seen that the collided leaf will only produce leafs in the next level of the tree stucture.

The beauty of this algorithm is that this offers system efficiency that is close to the ideal Aloha based algorithm where the system efficieny of 36.8% is achived when the number of collided tags are exactly known. On the other hand, with fixed splitting factor and without knowing the numer of tags, the binary tree and ternary tree algorithms can achieve system efficiency of 34.6% and 36.4 % of system efficiency, respectively.

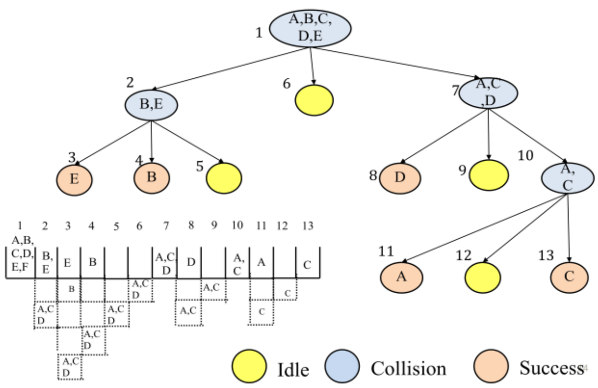

Figure 2 An example of a tree structure of collision resolution with tree algorith when Q = 3

Another variation of tree algorithm that is also introduced by Capetanakis is dynamic tree algorithm [4]. In fact, the basic tree algorithm and dynamic tree were introduced under scenerio of Poisson travic arrival. The dynamic tree algorithm was designed to improve the performance of the basic tree algorithm whereby the splitting mechanism depends on the traffic condition. This variation aims to devide the collision into smaller groups such that each group consist of small number of collision multiplicity. Then the basic binary tree algorithm will be applied in each group. So, the number of groups in the first splitting is the key performance of the dynamic tree algorithm. In Capetanakis's study, it is found that this dynamic tree algorithm can achieve system efficiny of 43.3% when the first splitting change according to the arrival rate of the packets.

2.3 Tag estimation method

Since there is no information about the number of collided tags, tag estimation method is required in RFID systems. This is normally used to determine the frame size in framed slotted Aloha. Following are several estimation method used in RFID systems.

Vogt proposed a tag estimate method that considers the number of idle, success and collisions [8]. It calculates the Euclidean norm of the difference between the expected values of number of idle, success and collisions (c_0, c_1 and $c_{>2}$, respectively) and their actual values and minimizes it based on Mean Square Error (MSE) estimation as given by:

$$\varepsilon = \min_N \left\| \begin{pmatrix} c_0 \\ c_1 \\ c_{\geq 2} \end{pmatrix} - \begin{pmatrix} I \\ S \\ C \end{pmatrix} \right\| \quad (1)$$

The calculation of MSE given in (1) will with $N = S+2C$ since it is the minimum number of tags contending in a frame and will stop when it reaches the minimum value.

Solic in [9] proposed an energy efficient tag estimation method that is called as Improved Linearized Combinatorial Model (ILCM) which uses an efficient interpolation method based on the calculation of the combinatorial model. It uses the statistic of the empty, success, and collision slots in the frame to achieve a good estimate of $N = \text{argmax } N \{p(I, S,C)\}$. The interpolation in ILCM much reduces the complexity of the algorithm with the following estimated method:

$$\hat{N} = kS \quad (8)$$

where

$$k = \frac{C}{\left(4.344L - 16.28\right) + \left(\frac{L}{-2.282 - 0.273L}\right)C + 0.0207\ln\left(L + 42.56\right)}$$

$$l = \left(1.2592 + 1.513L\right)\tan\left(1.234L^{-0.9907}C\right) \quad (9)$$

With the interpolation method, ILCM is easily implemented and results in a modest FLOP cost. However, the performance degrades with the increase in the number of tags.

Chen in [10] proposed a tag estimation method namely a feasible and easy to implement anti-collision algorithm (FEIA) that estimates the number of tags slot by slot in the frame by the following expression:

$$\hat{N} = \left(S_i + kC_i\right)\frac{L}{i} \quad (10)$$

where S_i and C_i are the number of single occupied slots and the number of collisions, respectively, from slot 1 to slot i. k can be set to 2 indicating the minimum number of tags involved in a collision or 2.39 as suggested by the Schoute's method. This method is simple to implement yet there is constraint that the first slot in the frame should not be an idle slot.

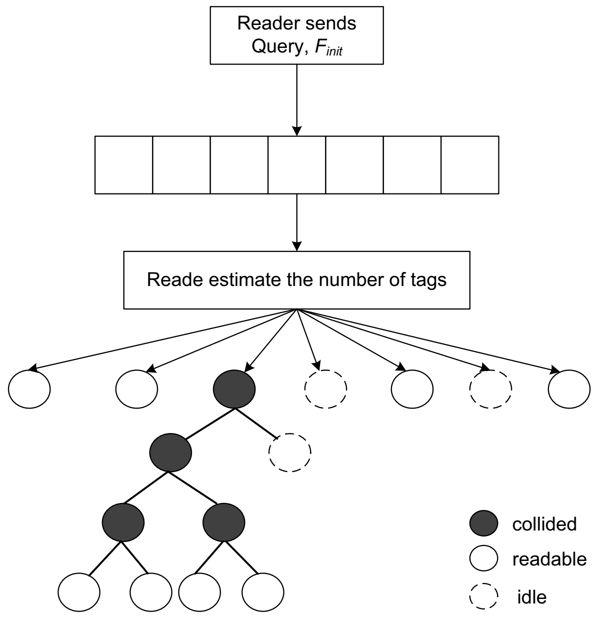

Figure 3 The proposed hybrid anti-collision algorithm

3. System Model

In this work, we consider a RFID system for identifying multiple tags with hybid algorithm that includes framed slotted Aloha and tree algorithm. Frame slotted Aloha is used to estimate the number of tags that is further used to determine the first level splitting factor fo the dynamic tree algorithm. The proposed algorithm is illustrated in Figure 3. At the beginning of the identification process, the reader will send a Query command to the tags. The Query command is basically provide a frame that is a number of slots for the tags to choose from for sending their responses. The aoutcome of this frame is basically used for the system to estimate the number of collided tags. We use low complexity estimation method, ILCM model, for estimating the number of tags. After the number of tags is estimated, the system will perform dynamic tree algorthm to continue the identification process. The rest of the collided tags will be split into the number of estimate tags and continue with traditional binary tree algorithm.

4. Performance Analysis

In this section we compare the performance of the proposed algorithm and the existing binary, ternary and the ideal dynamic tree algorithm with respect to simulated system efficiency.

From the results in Figure 4, it can be seen that our simulation prove that the existing binary, ternary and dynamic tree algorithms achieve 34.6%, 36.4% and 43.3% of system efficiency, respectively. It also shows that improvement to the binary and ternary tree algorithm is achieved by our proposed hybrid algorithm. However, the improvement depends on the initial frame, F_{init}, frame size. When the initial frame size is close to the number of collided tags, high efficiency is achieved. It can offer system efficiency of least 38.1% when the frame size is 32. With frame size of 128, the proposed algorithm provides system efficiency of 40.03%.

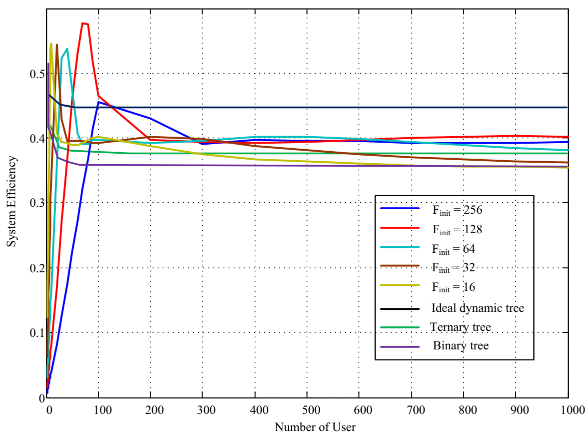

Figure 4 Comparison of the proposed algorithm and the existing tree algorithm

5. Conclusion

In this paper, we proposed a hybrid algorithm for tags anti-collision process. Normally, it is difficult to perform dynamic tree algorithm since the number of tags in each collision is unknown. We use frame slotted Aloha for tags estimation purpose before performing dynamic tree algorithm. The simulation results show that the proposed algorithm work well where significant improvement to the existing basic tree algorithm is achieved.

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